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Design and Fabrication of Shock Absorbing Damper for High Vibration

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***Abstract*: In the regard of earthquake technology is growing very fast in 21st century and is needed to utilize for the protection of most valuable thing on the earth i.e. human life in safest form. To minimize the risks from high vibration of earthquake shock observant technology has been developed and hence the concept of damper came in existence. This paper is presenting the working model and utility of MR (Magneto rheological) fluid damper which can reduce the stress, deflection, absorb shock & vibration produce during earthquake in structural buildings. Different parameters like damping coefficient of fluid, damping factor, natural frequency, damped frequency, masses, floor displacements, floor velocity and acceleration have been considered in calculation to show the reduction in deflection and vibration caused during earthquake.**

***Keywords*: MR fluid Damper, deflection, shock & vibration, co-efficient of fluid, structural building.**

1. Introduction

The dampers or shock absorbers are widely used in automotive vehicles to dissipate the vibration energy of sprung and un-sprung mass under resonance conditions. Damping – is the ability of a vibrating system or structure to dissipate energy. Mostly – mechanical energy is converted to heat energy when the dissipation is by internal friction or hysteresis characteristics due to its molecular structure–material damping. When it is generated by the friction, snapping, rubbing, slapping or impacting at the joints and interfaces of structural assemblies, - it is structural damping. A damping system in a building is much larger and is also designed to absorb the violent shocks of an earthquake. The size of the dampers depends on the size of the building.

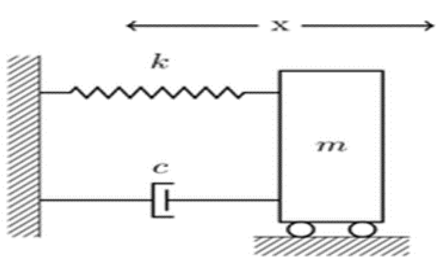

Fig. 1. Mass–spring–damper

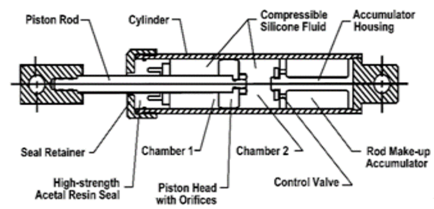

Fig. 2. Components used in fabrication of damper

2. Types of Damper

There are three classifications for dampening systems:

Passive: This is an uncontrolled damper, which requires no input power to operate. They are simple and generally low in cost but unable to adapt to changing needs.

Active: Active dampers are force generators that actively push on the structure to counteract a disturbance. They are fully controllable and require a great deal of power.

Semi-Active: Combines features of passive and active damping. Rather than push on the structure they counteract motion with a controlled resistive force to reduce motion. They are fully controllable yet require little input power. Unlike active devices they do not have the potential to go out of control and destabilize the structure.

3. Components used in fabrication of fluid damper

Piston rod, cylinder, fluid, seal, piston head, seal retainer, accumulator, orifices

- *Piston rod:* Highly polished on its outside diameter, the piston rod slides through the seal and seal retainer. The external end of the piston rod is affixed to one of the two mounting clevises. The internal end of the piston rod attaches to the piston head the piston rod must react all damping forces and provide a sealing interface with the seal.
- Since the piston rod is relatively slender and must support column loading conditions, it is normally manufactured from high-strength steel material.
- *Cylinder:* The damper cylinder contains the fluid medium and must accept pressure vessel loading when the damper is operating. Cylinders are usually manufactured from

seamless steel tubing.

- Welded or cast construction is not permissible for damper cylinders, due to concerns about fatigue life and stress cracking.
- *Fluid:* Fluid i.e. fire-resistant, non-toxic, thermally stable, and which will not degrade with age. The fluid path in the MR damper used in this study is slightly different from a conventional twin tube damper. As a conventional twin-tube damper compresses, the fluid flows from the inner cylinder, as shown in Figure, to the outer cylinder through the foot valve. In the outer cylinder there is a free air and fluid interface. As more of the piston rod enters the volume previously available to the fluid, the air column fills the function of an accumulator by compressing. When the damper is in extension, the flow directions are reversed.

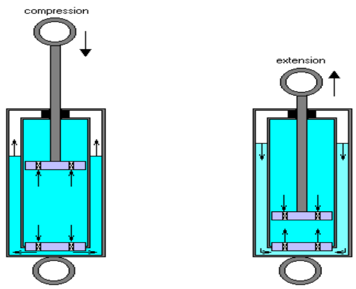

Fig. 3. Conventional twin-tube damper flow direction

- *Seal:* The seals used in a fluid damper must be capable of a long service life; at least 25 years without requiring periodic replacement. Material of the seal must be carefully chosen for this service life requirement and for compatibility with the damper's fluid.
- *Piston Head:* The piston head attaches to the piston rod, and effectively divides the cylinder into two pressure chambers. As such, the piston head serves to sweep fluid through orifices located inside it, thus generating damping pressure. The piston head is usually a very close fit to the cylinder bore; in some cases the piston head may even incorporate a seal to the cylinder bore.
- *Seal Retainer:* Used to close open ends of the cylinder; these are often referred to as end caps, end plates, or stuffing boxes. It is preferable to use large diameter threads turned on either the exterior or interior surface of the cylinder to engage the seal retainer.
- Alternate attachment means, such as multiple bolts, studs, or cylinder tie rods should be avoided as these can be excited to resonance by high frequency portions of either the earthquake transient or the building response spectra.
- *Accumulator:* The simple damper depicted in Figure utilizes an internal, in-line rod make-up accumulator. The accumulator consists of a block of closed cell plastic foam, a moveable (and gas pressurized) accumulator piston, or a rubber bladder.
- The purpose of the accumulator is to allow for the volumetric displacement of the piston rod as it enters or exits the damper during excitation and to compensate for thermal expansion and contraction of the fluid. Accumulator when the damper is being compressed. When the damper extends, the control valve opens to allow fluid from the accumulator to freely enter the damper pressure chambers.

4. Working principle of fluid damper

- MR fluid dampers are semi-active devices that change their damping level by varying the amount of current supplied to an internal electromagnet that controls the flow of MR fluid.
- Inside the MR fluid damper, an electromagnetic coil is wrapped around three sections of the piston. Approximately 5 litres of MR fluid is used to fill the damper's main chamber. During an earthquake, sensors attached to the building will signal the computer to supply the dampers with an electrical charge. This electrical charge then magnetizes the coil, turning the MR fluid from a liquid to a near-solid. Now, the electromagnet will likely pulse as the vibrations ripples through the building.
- This vibration will cause the MR fluid to change from liquid to solid thousands of times per second, and may cause the temperature of the fluid to rise. A thermal expansion accumulator is fixed to the top of the damper housing to allow for the expansion of the fluid as it heats up. This accumulator prevents a dangerous rise in pressure as the fluid expands.
- Depending on the size of the building, there could be an array of possibly hundreds of dampers. Each damper would sit on the floor and be attached to the chevron braces that are welded into a steel cross beam. As the building begins to shake, the dampers would move back and forth to compensate for the vibration of the shock. When it's magnetized, the MR fluid increases the amount of force that the dampers can exert. Buildings equipped with MR fluid dampers will mitigate vibrations during an earthquake.

5. Working model

- Device construction.
- The construction procedure is based on the design procedure of making MR Fluid Damper in real practical situation.

Fig. 4. Working Model

1. Structure or frame
2. Damper
3. Motor
4. Cam

Fig. 5. Structure or frame

Table 1
Specification of the components

Total Weight	16 Kg
Base Dimension	3'mm*8''mm*8mm
Plate Dimension	15MC25*2ft
Channel Dimension	15MC25*2ft
Material Used	Cast Iron

Fig. 6. Damper

Table 2
Specification of the damper

Material used	Stainless steel
Fluid used	silicon fluid
maximum elongation	15 cm
Weight	2 kg each
No. of damper used	2 damper of same specification
Damping co-efficient	125 n/m/sec.

Fig. 7. Motor

Table 3
Specification of the Motor

Weight	2.5 Kg
Frequency of Motor	50 Hz
Input Voltage	220-240 Volt
H.P	1/7[1 H.P=746 Watt]
Speed	1370-2800 R.P.M

Fig. 8. Cam

Table 4
Specification of the Cam

Weight	250 Gm
Material Used	Cast Iron
Shape	Circular
Profile	Eccentric

6. Theoretical equations for calculating high vibration

For strong earthquakes a large portion of the input energy will be absorbed by hysteretic action (i.e., damage to the structure).

In this approach to seismic energy dissipation is made clear by considering the following time-dependent conservation of energy relationship (Uang and Bertero, 1990):

$$E(t) = Ek(t) + E.(t) + Eh(t) + Ed\{t\} \quad (1)$$

Where,
E = the absolute energy input from the earthquake motion,
Ek = the absolute kinetic energy,
E. = the elastic (recoverable) strain energy,
Eh = irrecoverable energy dissipated by the structural system through inelastic or other forms of action (e.g., viscous and hysteretic),
Ed = energy dissipated by a supplemental damping system,
t = represents time.

The absolute energy input E, represents the work done by the total base shear force at the foundation on the ground (foundation) displacement and thus accounts for the effect of the inertia forces on the structure.

The different control theories are based on control system with both time varying and lumped parameters control operations. Some of the control methods (algorithms) are shown below. The mathematical equation of motion for all control methods has the following structure:

$$M\ddot{Y} + C\hat{Y} + KY + \Lambda F = -M\Gamma\ddot{Y}g$$

Where,
M = mass matrix,
C = damping matrix,
K = stiffness matrix,
Y = vector of floor displacements,
$\hat{Y}$ and $\ddot{Y}$ are floor velocity and acceleration vectors, respectively,
Λ is a matrix of zeros and ones, where one will indicate

where the MR damper force is being applied.

F= [f $d1$, f $d2$, f dn]^T (3)

F is the vector of control force produced by the dampers,
T is the influenced coefficient vector of ones and
$\ddot{Y}g$ is the acceleration due to an earthquake.

A full scale MR fluid damper i.e. 1-meter-long and weighs 250 kilograms. This one damper can exert 20 tons (200,000 N) of force on a building [4].

7. Experimental calculation according to working model

C=125 N/m/sec {Specified in damper}
Where, c=damping co-efficient
Deflection from experimental data without damper=15 cm =0.15 m
Hence, natural frequency, fn:

or, fn=1/2π * $\frac{\sqrt{g}}{\sqrt{\delta}}$

=1/2π * $\frac{\sqrt{9.81}}{\sqrt{.15}}$

or,ω =2π* fn

= $\frac{\sqrt{9.81}}{\sqrt{.15}}$

=8.087 rad./sec

Mass of the whole experimental set up, m =21 k.g

Now, damping factor,φ = c /2*m*ω

= 2*125/2*21*8.087

=.736

Now, damped frequency, ɰd = ω*$(\sqrt{1} - \sqrt{\varphi^2})$

=8.07*$(\sqrt{1} - \sqrt{.736^2})$

= 5.474 rad./sec

8. Effect of adding damper to the system

- Damping is one of many different methods that have been proposed for allowing a structure to achieve optimal performance when it is subjected to seismic, wind storm or other types of transient shock and vibration disturbances.
- Conventional approach would dictate that the structure must passively attenuate or dissipate the effects of transient inputs through a combination of strength, flexibility, deformability and energy absorption. The level of damping in a conventional structure is very low, and hence the amount of energy dissipated during transient disturbances is also very low.
- During strong motions, such as earthquakes, conventional structures usually deform well beyond their elastic limits, and remain intact only due to their ability to in elastically deform. Therefore, most of the energy dissipated is absorbed by the structure itself through localized damage.
- The concept of added-on dampers within a structure assumes that some of the energy input to the structure from a transient will be absorbed, not by the structure itself, but rather by supplemental damping elements.
- An idealized supplemental damper would be of a form such that the force being produced by the damper is of such a magnitude and occurs at such a time that the damper forces do not increase overall stress in the structure. Properly implemented, an ideal damper should be able to simultaneously reduce both stress and deflection in the structure.

9. Advantages

1. Passive energy dissipation is an emerging technology that enhances the performance of buildings by adding damping to buildings.
2. Displacement over 50% reductions in drift in many cases.
3. Decreased base shear and inter-story shear, up to 40%.
4. Much lower the gravitational forces in the structure. Equipment keeps working and people are not injured.
5. Reduced displacements and forces can mean less steel and concrete. This offsets the damper cost and can sometimes even reduce overall cost.

10. Limitations

1. Equipment is very costly.
2. High installation cost.
3. Proper designing is required.
4. High quality fluid is expensive
5. Fluids are subject to thickening after prolonged use and need replacing.
6. Heat is generated in shock absorber due to coil.

11. Applications

1. It has wide range of application from automobiles to railway vehicles in every field from mechanical to civil structures.
2. Magneto Rheological Shock Absorber used in several automobile those are: Acura MDX, Audi TT and R8, BMWs, Buick Lucerne, Cadillac DTS, Cadillac XLR, Cadillac SRX, Cadillac STS, Chevrolet Corvette, Ferrari 599GTB.
3. It is also used modern anti earth quake building base construction.

12. Result and Discussion

- From the working model and design calculation effect of adding the MR fluid damper can be easily observed in the reduction in vibrating system.
- The natural frequency of the experimental setup was 8.087 rad. /sec and after adding the damper to the system, the damped frequency reduced to 5.474 rad./sec.
- Other dampers can normally be classified as either hysteretic, where a fixed damping force is generated under any deflection, or as visco-elastic, where a damper behaves as a complex spring and damper combination.
- Devices used are dependent upon parameters other than, or in addition to, velocity. Hence, other types of dampers will decrease deflection in a structure, but at the expense of increasing stress. The out-of-phase response that is unique to fluid dampers can be easily understood by considering a building shaking laterally back and forth during a seismic event or a windstorm.
- Column stress is at a peak when the building has flexed a maximum amount from its normal position. This is also the point at which the flexed columns reverse direction to move back in the opposite direction. If the addition of fluid damper to the building, damping force will reduce to zero at this point of maximum deflection.
- This is because the damper stroking velocity goes to zero as the columns reverse direction. As the building flexes back in the opposite direction, maximum damper force occurs at maximum velocity, which occurs when the column flexes through its normal, upright position.

13. Conclusion

1. Both fluid viscous dampers and shock transmission units can be used to improve the seismic response of structures.
2. When fluid dampers are used for seismic or wind protection, the end result is a predictable reduction of both stress and deflection in the structure.
3. In recent years, their reliability, proven by many instances of application in bridges and demanding qualification tests, has lead to an increase of their use in buildings.
4. They have been used to improve both local and total structural responses.
5. This simultaneous stress and deflection reduction is unique to fluid dampers.
6. Optimal performance is dependent on the type of structure and the level of performance required. Damping levels for optimal use of this technology range from 10% critical to 45% critical.
7. The results of acceptance tests performed for many of the projects described above have confirmed the reliability of the aforesaid devices even for the small values of design force and design displacement that often characterize the devices used in buildings.
8. Today, more than 240 major buildings and bridges are using fluid dampers as a primary design element.
9. Damper sizes being used range from as little as 5 tonnes force to more than 800 tonnes force, with deflections as low as 25 mm and as high as 1.5 m.
10. Indeed, it can be said that the use of supplemental fluid dampers will be one of the primary solutions for seismic and wind protection in the structures of the 21st century.

14. Future Scope

1. Skyscrapers and long bridges are susceptible to resonance created by high winds and seismic activity. In order to mitigate the resonance effect, it is important to build large dampers into their design to interrupt the resonant waves.
2. If these devices would be place, buildings and bridges can’t be shaken to the ground and help to absorb the shock & vibration.
3. Dampers can be used in machines that we likely use every day, including car suspension systems and clothes washing machines. If we take a look the How Stuff Works article on washing machines, we will learn that damping systems use friction to absorb some of the force from vibrations.
4. Magneto-rheological dampers (MR dampers) are being developed for a wide variety of application where controllable damping is desired. These applications include dampers for automobiles (Ferrari F12 Berlinetta), heavy trucks (U.S. HMMVS), bicycles (BMW R 1200 GS Adventure), prosthetic limbs, gun recoil systems and others [4].

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